63-4-1

ARDE-PORTLAND, INC.
100 WEST CENTURY ROAD
PARAMUS, NEW JERSEY

TECHNICAL PROGRESS REPORT NO. 3

QUARTERLY PERIOD: 2/13/63 - 5/13/63

FABRICATION OF A 65.5-INCH-DIAMETER SIMULATED ROCKET MOTOR CASE BY CRYOGENIC STRETCH-FORMING

PREPARED FOR:

United States Air Force

Contract AF 33(657)9638

Prepared by: George Claffy
George Claffy
Project Engineer

Approved by: S. W. Henderson
S. W. Henderson
Program Manager

TABLE OF CONTENTS

1.0 PROGRAM OBJECTIVES

To demonstrate the applicability of the cryogenic stretch-forming process to the fabrication of large rocket motor cases of heavy wall thickness. Previous work, under government contracts, has shown the feasibility of fabricating high-strength rocket cases by cryogenic stretch-forming. See references in appendix. Effort under the present contract is directed at "scaling up" the equipment and techniques to handle the size and wall thickness of a big-boost motor.

1.1 Specific Contract Tasks

1.1.1 Materials Evaluation

1.1.1.1 Welding Characteristics: Determination of welding characteristics of 1/4-inch and thicker 301 stainless steel plate.

1.1.1.2 Tensile Testing: Tensile tests of welded and unwelded coupon samples prior to and after cryogenic stretching in a bath of liquid nitrogen at -320°F Specimens shall consist of coupons representing sections cut transverse (90°) and parallel to the rolling direction of the plate.

1.1.1.3 Hardness - strength correlation: Determine relationship between weld material hardness and strength characteristics. Weldments, unstrained, strained, and in the strained-and-aged conditions to be investigated.

1.1.1.4 Charpy Impact Tests: Testing of welded and unwelded specimens at room temperature and -320°F to obtain correlative data for notch sensitivity of the weld.

1.1.1 (Cont'd)

1.1.1.5 ASTM Center Notch Test: Testing of specimens in the unstrained, strained, and strained-and-aged conditions to obtain correlative data for notch sensitivity.

1.1.2 Vessel Fabrication

1.1.2.1 Fabrication and testing of small-scale vessels, approximately 25" in diameter, to verify weld and dome-forming techniques.

1.1.2.2 Design and procurement of a full-scale stretch-forming die to control cylinder roundness and straightness.

1.1.2.3 Fabrication and cryogenic stretching of a simulated rocket motor case, 65.5" in diameter, with a target strength level of 275,000 psi nominal hoop yield.

1.1.2.3.1 Hydrotest of stretched vessel to determine yield point.

1.1.2.3.2 Age - After hydrotest, the vessel will be age-hardened to augment strength.

1.1.2.3.3 Hydroburst - Burst test to determine yield point and ultimate strength of the cryogenically stretched and age-hardened vessel.

2.0 SUMMARY

Three sub-scale vessels were fabricated and stretched. Two of these were weld development vessels evaluating the sigma/heliarc-root and 2-pass heliarc welds respectively. One test established that the sigma/heliarc-root weld, blended flush at the underbead, is acceptable for stretching. The vessel incorporating the 2-pass heliarc weld sustained a premature failure which was not weld-involved. It is not possible to conclude whether the 2-pass heliarc weld would be a satisfactory alternate for cryogenic stretching. The third sub-scale unit was a dog-bone vessel which was run to evaluate the hot-spun dog-bone parts. It is concluded, as a result of this test, that the spun parts, one of which incorporates a vendor weld, are satisfactory for cryogenic stretching.

A simple full-scale vessel was partially assembled as a practice unit to gain handling, machining, and welding experience in this large size. This was necessary since ARDE-PORTLAND's prior experience has been limited to much smaller vessels.

A set-back in the notch toughness phase of the program was encountered when one of the clevis bars for pulling the large tensile specimens failed during test. The failure was traced to an internal material flaw. Fabrication of a replacement clevis was initiated at once with provision for special inspection techniques to assure material quality. A delay of one month in the start of the notch toughness phase is anticipated as a result of the clevis failure.

An extension of the completion date of the current program was requested during the report period. Formal approval of this request was also received during the report period, and hardware effort on the program will now extend into July, 1963.

3.0 COORDINATION WITH U.S.A.F.

3.1 Reports: Three monthly reports were submitted during the quarter as follows:

Monthly Progress Report No. 7 - 2/13/63 to 3/13/63
Monthly Progress Report No. 8 - 3/13/63 to 4/13/63
Monthly Progress Report No. 9 - 4/13/63 to 5/13/63

3.2 Conferences:

3.2.1 On 15 April 1963, a conference was held at Wright Patterson Air Force Base between Air Force and ARDE-PORTLAND personnel. The following were in attendance:

Mr. Max Guenther	A.F.	ASD Proj. Officer
Mr. John Snyder	A.F.	Fabrication Branch
Mr. S. W. Henderson	A-P	Program Manager
Mr. R. H. Alper	A-P	Program Management
Mr. A. J. Scarp	A-P	Field Representative
Dr. O. G. McKee	A-P	Preliminary Design

The purpose of the meeting was to discuss a time extension for the program. An extension of approximately four months was requested. The factors contributing to the need for this extension are as follows:

1. Difficulties in procuring the proper chemistry 301 stainless steel in .250" thickness.

2. Problems in bringing the large stretch pit to operational status.

3. Problems in developing optimum welds, for cryogenic stretching, in the .250"-thick material.

4. Vendor delays in producing the material specimens.

5. Delay due to failure of the clevis for pulling tensile specimens.

During the report period, the extension was received from A.S.D. in the form of Contract Modification No. 2. It should be noted that this time extension does not affect funding in any way. The program will be completed within the original dollar value of the contract.

4.0 DISCUSSION OF ACTIVITY

4.1 Sub-Scale Vessels: Vessel #2107 was cryogenically stretched and hydrotested during the report period. The objective was to prove out the sigma/heliarc-root type weld with underbead blended flush. The vessel stretched successfully to a true hoop stress of 272,000 psi, a value which stretched the vessel 12.8% in diameter. This is the first vessel which sustained the required forming stress without failure, and this signifies the successful development of a satisfactory weld configuration for cryogenic stretching in material of .250" wall thickness. Blending of the underbead, in the successful weld, eliminated the previous type of failure which had occurred through the notch-like juncture of weld nugget with parent metal. Leaving the overbead "as welded" has eliminated premature failures associated with thin-out of the more ductile weld metal when blended flush at the overbead. The extra weld metal at the top compensates for the thin-out effect. Experience has shown that the juncture of overbead with parent metal is not critical, with respect to its notch effect, and therefore need not be blended.

Since Vessel #2107 utilized the same heat of 301 stainless steel as will be used in the full-scale vessels, it was decided to age and hydrotest to determine aged strength. The vessel was subjected to an age at 800°F for twenty hours and then hydrotested to destruction at room temperature. The ultimate strength of the vessel was 283,000 psi. Strain gages were not installed for this sub-scale test, but previous experience has shown that the yield and ultimate strengths for cryogenically stretched and aged material are very close. This test demonstrates that the contract strength requirement of 275,000 psi minimum yield is within the capability of the process and the material. Figure 1 is a photograph of the vessel after the hydrotest to burst.

4.1 (Cont'd)

Vessel #2111 was also cryogenically stretched during the report period. The purpose was to evaluate a 2-pass heliarc weld as a possible alternate weld for cryogenic stretching of .250"-thick material. The vessel encountered a premature failure which was not weld-involved. The fracture passed through a sharp gouge-like mark in the parent metal of the cylinder, remote from the weld. Figure 2 is a photograph of the vessel after burst. Failure stress was approximately 140,000 psi, a value too low for any conclusions about the 2-pass heliarc weld. The defect which caused failure was apparently imparted during handling after initial inspection of the cylinder. Due to limitations of time and funds, no effort will be made to repeat this test and evaluate the 2-pass heliarc weld. The proven sigma/heliarc-root weld will be utilized in the full-scale vessel.

The third unit stretched during the period was Vessel #2110. This vessel was dog-bone-shaped at one end with a hemispherical closure at the other end of the cylinder. Figure 3 is a photograph of the preform vessel. The dog-bone end was fabricated with spun parts. The objective was to evaluate the spun parts, one of which incorporated a weld made by the vendor. It was deemed necessary to stretch a set of parts, fabricated in this manner, in a sub-scale vessel prior to building the 65"-diameter vessels with parts made in the same way.

The vessel sustained a high stress level failure upon stretching. Rupture occurred at a true hoop stress of 230,000 psi. No discrepancies were observed in the spun parts, including the weld made by the vendor. An irregular underbead in the cone-to-cylinder weld was the cause of failure. The fracture passed through an area where the weld sagged excessively and probably acted like a notch in raising the local stress.

4.1 (Cont'd)

This test points up another situation which has been neglected up to this time. This is the importance of blending the underbead on a girth weld. It was found in earlier tests that the critical longitudinal weld could not sustain the hoop stress imposed by stretching, unless the underbead was blended smooth to eliminate notch effects. Since the girth welds feel half the stress taken by the longitudinal weld, the precaution of blending the underbead has been bypassed until now. One reason for this has been the difficulty in working inside a 22"-diameter vessel. In the full-scale vessel it will be possible to conveniently blend the underbead of all the girth welds except the final one which closes up the vessel. This is the approach which will be taken; and the final weld, which will remain unblended, will be a cone-to-end-plate weld, which is required to stretch the least.

4.2 Materials Evaluation: The testing portion of this phase was initiated during the report period. The cryostat reached Thiokol/Wasatch and was set up on the tensile machine. On the first tensile specimen pull, a failure of the upper clevis arm was encountered at 140,000 lbs. load. The failure was traced to a sub-surface crack at a non-metallic inclusion in the 17-4 PH material. The clevis had been given a thorough surface examination, but this internal condition was not detected. Fabrication of a replacement clevis was initiated, and this will be completed early in the next report period. Extra precautions will be taken to avoid a similar flaw in the new clevis. The forging to be used will receive an ultrasonic inspection to detect internal flaws prior to machining. The finished part will receive a modified heat-treatment to a condition which improves notch properties at a slight sacrifice in strength. This will make it less sensitive to minute flaws which might go undetected in inspection.

4.2 (Cont'd)

Deliveries of the large tensile specimens commenced during the report period. Figure 4 is a photograph of one of the .500"-thick specimens. Note the heavy reinforcing plates needed to accommodate the high tensile load, which can be as much as 250,000 lbs. At this writing, the procurement of tensile specimens is approximately 30% complete and continuing at a rate which ensures no delay in the program when the replacement clevis is complete.

4.3 Full-Scale Vessels: The tests described in Section 4.1 above represent the completion of the sub-scale vessel phase of the program. The remaining vessel work in the program will be in the full-scale size, approximately 58" preform diameter. The full-scale vessel effort will consist of one practice vessel with simple heads and two vessels with spun dog-bone closures to stretch into elliptical heads.

During this report period the only full-scale hardware effort was on the simple vessel. Work on the dog-bone vessels was limited to procurement. The simple vessel is a practice unit to develop machining, handling, and welding techniques. The vessel will not be cryogenically stretched since it is known that this type of preform will not satisfy the configurational requirements of the contract when stretched. During the report period, a satisfactory sigma/heliarc-root longitudinal weld was made; the bosses were welded into the heads; and both heads were positioned on the cylinder by tack welds. The final girth welds will be made just prior to welding the dog-bone vessels in order to check out the weld settings.

4.4 Stretch Facility: ARDE-PORTLAND's new stretch facility, for vessels in the 65"-diameter range, was completed and checked out during the report period. The three sub-scale

4.4 (Cont'd)

vessels discussed earlier in this report were stretched in the new facility. The usual start-up problems were encountered and corrected before the vessels were stretched. Both the high-capacity and low-capacity pumps were checked out. The low-capacity pump was able to stretch a 22"-diameter vessel in fifteen to twenty minutes, verifying calculations made when the facility was designed. Similar calculations indicate that the high-capacity pump will stretch a full-scale vessel in approximately one hour.

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APPENDIX

References

Figure 1	-	Vessel #2107 after hydrotest to burst.
Figure 2	-	Vessel #2111 after burst.
Figure 3	-	Dog-bone type preform. Vessel #2110.
Figure 4	-	Tensile specimen - .500" thickness.
Table I	-	Data Summary for vessels tested.

REFERENCES

1. ARDE-PORTLAND final report, "Development of Ultra-High-Strength Rocket Motor Cases by Cryogenic Stretch-Forming", U.S. Army Ordnance Materials Research Office, Contract DA-30-069-ORD-3099 Task A, February 15, 1962.

2. ARDE-PORTLAND final report, "Cryogenic Stretch-Forming of Rocket Motor Cases", Navy Bureau of Weapons, Contract NOw 60-0263-C, May 15, 1961.

Figure 1 - Vessel #2107 after hydrotest
to burst

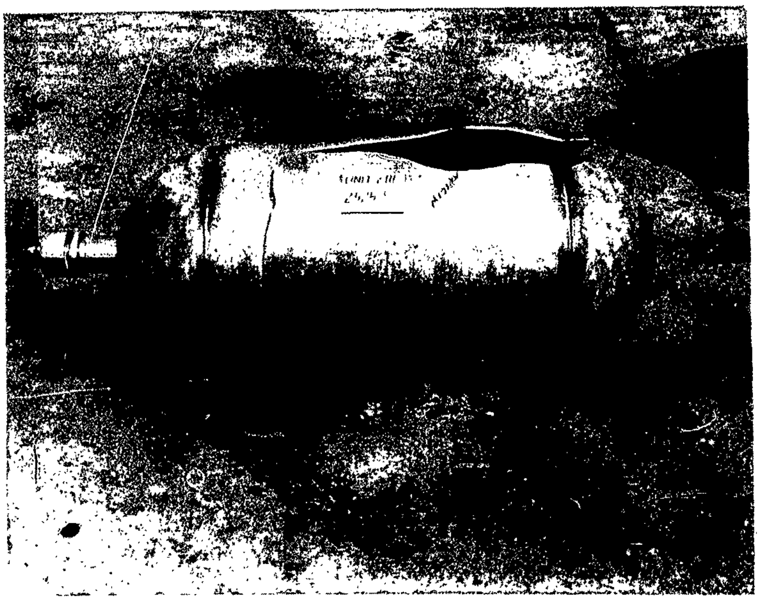

Figure 2 - Vessel #2111 after burst

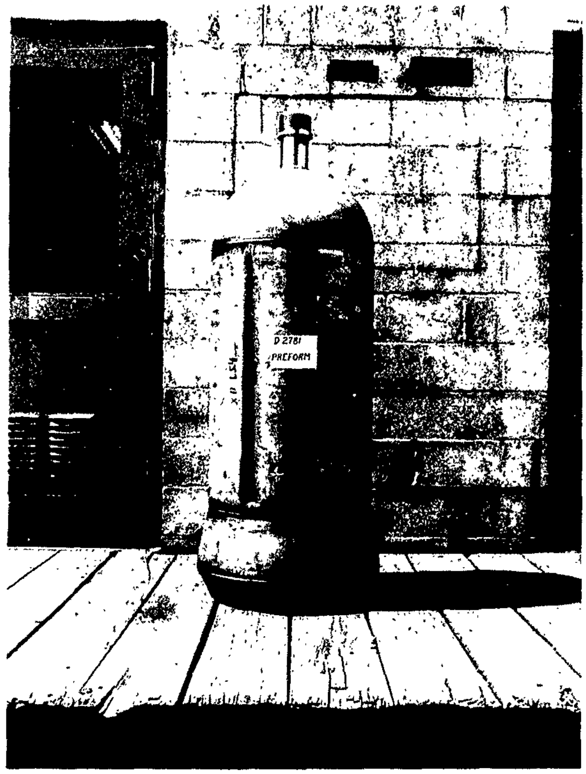

Figure 3 - Dog-Bone Type Preform.
Vessel #2110

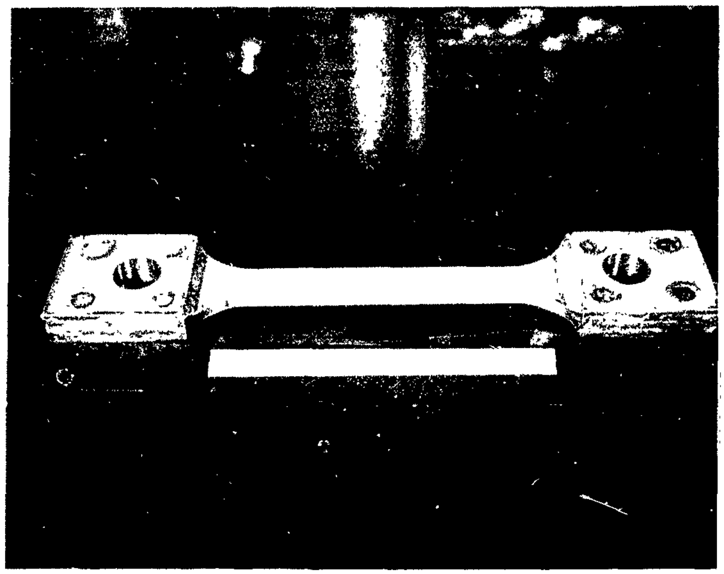

Figure 4 - Tensile Specimen - .500" Thickness

T A B L E I

DATA SUMMARY FOR VESSELS TESTED

Vessel No.	Type	Cyl. Heat	Weld	Result	Stretch Press.	Equiv. Cyl. Hoop Stress	Remarks
2102	Simple 22"	E 72145	Sigma/Heli blended over & under.	Burst	4750	245,000 psi	Failed thru tool mark in parent metal. Not weld-involved.
2100	Simple 22"	E 72145	Pure Sigma No blend	Burst	3220	157,000 psi	Failed thru longitudinal "weld notch".
2101	Simple 22"	E 72145	Pure sigma No blend	Burst	3040	147,000 psi	Failed thru longitudinal "weld notch".
2103	Simple 22"	M 58044	Sigma/Heli. No blend	Burst	3580	177,000 psi	Failed thru longitudinal "weld notch".
2104	Simple 22"	E 72550	Pure Sigma Blended over & under	Burst	4680	241,000 psi	Failed thru longitudinal weld which thinned-out excessively.
2106	Simple 22"	E 72550	Sigma/Heli. Blended over &under	Burst	5140	274,000 psi	Failed thru longitudinal weld which exhibited some degree of thin-out.
2107	Simple 22"	E 72550	Sigma/Heli Blended under only	Successful Stretch	4850	272,000 psi	Longitudinal weld flush after stretch, overbead compensated for thin-out.
2110	22" Dog-Bone	E 72550	Sigma/Heli Blended under only	Burst	4250	226,000 psi	Fracture remote from longitudinal weld - passed thru sagged underbead @ girth weld.
2111	Simple 22"	M 58044	2-pass Heli Blended under only	Burst	2525	128,000 psi	Failed thru tool mark in parent metal - not weld-involved.